PATENT SPECIFICATION

DRAWINGS ATTACHED

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COMPLETE SPECIFICATION

Improvements in or relating to Production of Fluids from a Plurality of Well Formations

We, SUN OIL COMPANY, a corporation organized under the laws of the State of New Jersey, United States of America, of 1608, Walnut Street, Philadelphia, Pennsylvania, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to the production of hydrocarbons from wells and more particularly is directed to method and means for producing well fluids from a plurality of formations penetrated by a well.

In well drilling practice a single well may traverse a plurality of formations which contain oil or gas. It is often desirable in such cases to complete the well for simultaneous production for more than one of the formations penetrated. The conventional procedure for doing this is to effect a dual completion and flow from a lower formation through the well tubing while flowing from a higher formation through the annulus between the tubing and casing. Chokes are provided at the well head for separately regulating the rates of flow of the two streams to conform to the allowable production rates for each zone.

The foregoing method of dually completing a well is unsatisfactory for several reasons. Production through the annulus is hazardous due to the fact that the fluid stream tends to cause corrosion and erosion of the casing, thereby allowing the possibility of a blow-out or subterranean loss of hydrocarbons to an upper formation. Also, when it becomes necessary to utilize gas lift to effect flow from the formations, the gas lift can be applied for only one zone at a time and that only in an inefficient manner; and consequently both production strata cannot be depleted simultaneously. In many cases this results in large quantities of otherwise recoverable oil being left in the reservoirs. A further unsatisfactory condition arises when the annulus well begins to produce salt water. Due to inefficient flow in the annulus, salt water accumulates therein and thus loads up the well and stops the oil flow. Production from that zone then is generally abandoned. Later attempts to produce from such zone after the other zone has become depleted often fail to restore the production. Still another drawback in conventional dual completions results from paraffin accumulations in the annulus which are difficult to remove.

An object of the present invention is to provide means for completing a well for simultaneous production from two or more zones while avoiding the disadvantages of conventional dual completions such as those described above. Still another object is to provide means and method for multiple zone production from a well through the well tubing under conditions such that flow from a zone of relatively high pressure can be utilized to effect or aid the flow from one or more zones in which the pressure is too low normally to permit the desired rate of flow therefrom.

Operation of a well according to the invention involves the use of one or more flow control devices, hereinafter described, which are positioned in the well tubing adjacent the production formations. Fluids from the formations pass as separate streams through the flow control devices and thereafter commingle in the tubing and flow from the tubing at the well head as a single stream. The flow control devices contain choke means which cause a fluid stream from a zone of high pressure to undergo a sharp pressure drop prior to commingling with another stream. The resulting pressure reduction causes or facilitates the flow of fluids from one or more of the zones of relatively low pressure. By operating in this manner oil from a high pressure zone will release solution gas as the pressure is reduced and the lifting effect of the released gas and any free gas already present in the oil stream

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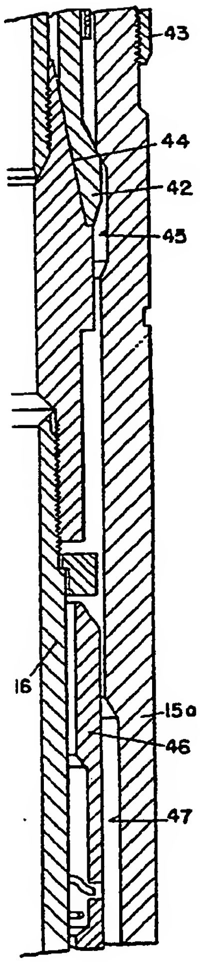

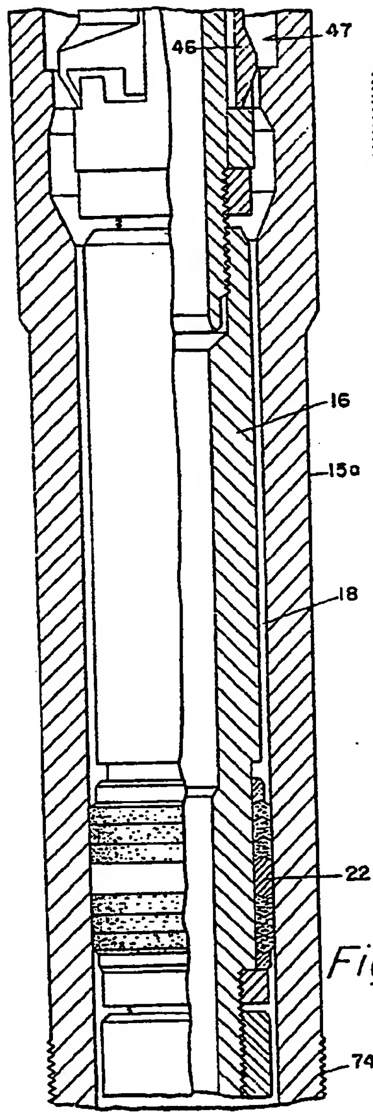

Fig.4C

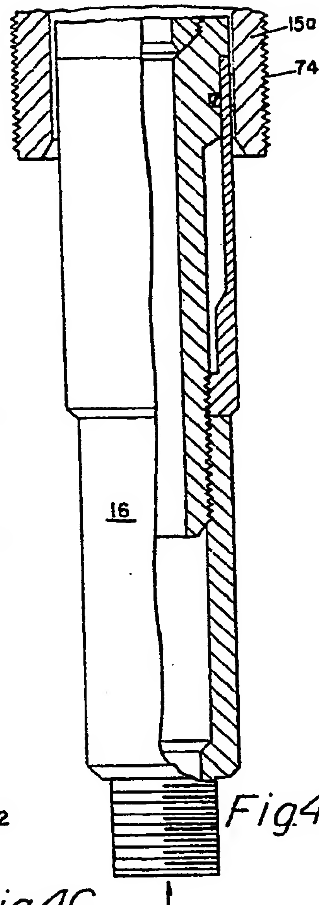

Fig.4D

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Fig. 4A

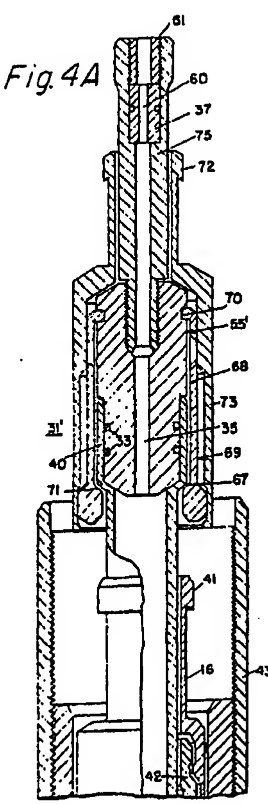
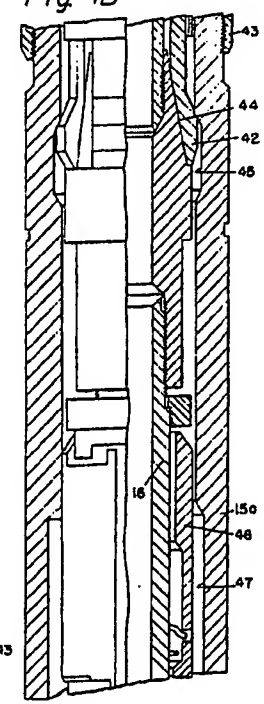


Fig. 4B



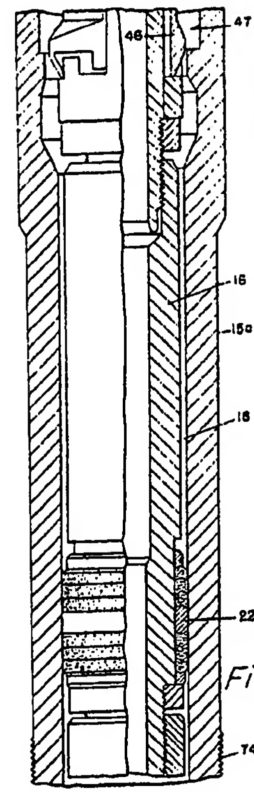


Fig 4C

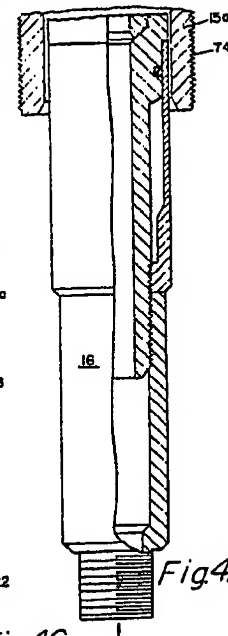


Fig 4D

tube 57 is provided with a plurality of inclined bores 58, which communicate at their lower ends with the interior of housing 16 below packing means 34 and at their upper ends with the interior of tube 57, i.e. with the fluid flow passage 35. It should therefore be apparent that the internal fluid flow passage 35 (interior of tube 57) communicates (by way of bores 58) with the outer housing flow channel 51, 52. Fluid from the lower Zone B thus flows into tube 57 by way of side ports 20, channel 51 (past valve 24), bores 52, the interior of outer housing 16, and bores 58. This fluid flows upwardly inside tube 57 (passage 35).

At weldment 56, an offset channel 59 is coupled to the upper end of tube 57, channel 59 leading upwardly through the body 55 of the inner housing (orifice head assembly) to the lower end of a replaceable choke 37 having a carbide-faced throat 60. Choke 37, through which all the fluid from the lower zone thus passes, controls the rate of flow of this fluid. Choke 37, whose throat or passage 60 extends longitudinally of body 55, is held in position at the upper end of inner housing 31 by means of a threaded nut 61, which has an axial opening therethrough and which threads into a tapped aperture at the upper end of housing 31.

In the body portion 55 of inner housing 31, there is provided a short sleeve 62 which surrounds but is space from tube 57. This sleeve carries a pair of O-rings 33, to provide a seal between the outer surface of the sleeve and the inner wall of the running neck 40 of outer housing 16. In effect, then, the orifice head assembly 31 seats in the running neck 40 of the outer housing 16. The annular space provided between tube 57 and sleeve 62 communicates at one end with annulus 32 (of outer housing 16), and at its opposite end with an annular chamber 63 (provided by the body of inner housing 31) which surrounds channel 59.

To the upper end of chamber 63, a channel 64 is coupled, channel 64 leading upwardly through the body 55 of the inner housing (orifice head assembly) to the lower end of a replaceable choke 39 having a carbide-faced throat 65. Choke 39, whose throat or passage 65 extends longitudinally of body 55, is held in position at the upper end of inner housing 31 (and parallel to choke 37) by means of a threaded nut 66, which has an axial opening therethrough and which threads into a tapped aperture at the upper end of housing 31.

Fluid from the upper Zone A flows into channel 64 by way of ports 17, annulus 18, side ports 19, channel 53 (past valve 23), bores 54, annulus 32 (in which it flows upwardly), the annular space within sleeve 62, and annular chamber 63. Choke 39, through which all of the fluid from the upper zone passes, control the rate of flow of this fluid.

The fluids from the two Zones A and B are mixed or commingled above (i.e., downstream of) the two chokes 37 and 39 (see Fig. 1). This process may be termed subsurface commingling.

It has previously been stated that the chokes 37 and 39 are carbide-faced; thus, they are made of an extremely hard material and have long life. Moreover, they are of standard size, so that predetermined producing rates for the zones can be set.

The width (i.e., the vertical dimension) of the entrance slots 20 is less than the diameter of choke passage 60 in the lower zone choke 37. Likewise, the width (i.e., the vertical dimension) of the entrance slots 19 is less than the diameter of choke passage 65 in the upper zone choke 39. This feature provides a screening effect for the inlet ports of the tool. Particles large enough to stop up or clog the chokes are prevented from entering the tool and then finding their way to the chokes, due to the smal size of the entrance slots at the inlet ports.

It has been stated previously that the inner housing 31 (orifice head assembly) is a separate member, which is retrievably fastened in position in the outer housing 16. The orifice head assembly 31 is run and pulled independently of the outer housing 16. The structure for retrievably fastening assembly 31 in position will now be described.

The running neck 40 of outer housing 16 has a diameter greater than does the main body of this housing, and at the junction between this neck and the housing main body there is provided a beveled (frusto-conical) surface 67 which extends outwardly and upwardly with respect to the housing body. A plurality of elongated fingers 68, together forming a collet 69, are mounted at their upper ends in a circumferential recess 70 near the upper end of the body portion 55 of the orifice head assembly 31. Thus, the fingers 68 are rather rigidly fastened to body portion 55 of assembly 31. At their lower ends, fingers 68 have inwardly and downwardly-extending tapered surfaces 71 (complementary to the surface 67) which, in the locked position illustrated in Fig. 2, fit under the surface 67 of the running neck 40, to lock the inner housing 31 in position in the outer housing 16, i.e., to fasten inner housing 31 in position and prevent upward movement of the latter in outer housing 16. It will be remembered that fingers 68 are rigidly secured to the inner housing body 55.

Chokes 37 and 39, and retaining or mounting nuts 61 and 66, are positioned in the running neck or orifice head 31, which is integral with or fixedly secured to the main body 55 of housing 31.

The orifice head assembly 31 carries a

pulling neck 72 which is slidable on the main body 55 of this assembly, so that it is slidable with respect to the fingers 68, secured to such body. Integral with the pulling neck 72 is a locking sleeve 73 which surrounds the fingers 68 and, when driven down to the position illustrated in Fig. 2 prevents outward movement of the lower ends of these fingers, and maintains the finger surfaces 71 locked under the surface 67 of running neck 40. That is to say, sleeve 73 serves as a locking means for the collet 69.

When the locking sleeve 73 is in the "up" or "running" or "pulling" or "unfastened" or "unlocked" position illustrated in Fig. 3, that is, when this sleeve is riding on the upper taper of the collet fingers, the lower ends of the collet fingers (i.e., surfaces 71) are free to move outwardly from under the running neck beveled surface 67, thus permitting vertical movement of inner housing 31 with respect to the outer housing 16.

The orifice head assembly 31 is run and pulled independently of the outer housing 16. As previously described, the tube 57 is adapted to fit into the bore of the outer housing 16, and when the tube is in its ultimate or operating position, the O-rings 34 provide a seal between the outer surface of this tube and the inner wall of housing 16, below the outer housing ports 54. Also, in the ultimate position of assembly 31, sleeve 62 of this assembly seats in the outer housing running neck 40.

When going into the hole with the orifice head assembly 31 (assuming that the outer housing 16 has previously been locked in position in the hole), the locking sleeve 73 is held in the "up" position (i.e., in the position illustrated in Fig. 3, with this sleeve riding on the upper taper of the fingers 68 which comprise collet 69) by the running tool (not shown), which is used on a wire line. When the running neck 40 of the outer housing 16 is reached by the collet fingers 68, these fingers spring out and pass over this running neck. There is enough flexibility in these fingers (which are rigidly secured only at their upper ends to the inner housing body portion 55, as previously described) to allow passing over running neck 40. Sleeve 73 is at this time in a position such as to allow this outward movement of the lower end of finger 68.

When the collet fingers have passed below the beveled surface 67 at the lower end of neck 40, the fingers retract (i.e., move inwardly) and fit under this neck. By suitable manipulation of the wire line equipment, the locking sleeve 73 is then driven downwardly, to the position illustrated in Fig. 2, to fasten or lock the orifice head assembly in position in outer housing 16. In the Fig. 2 position, the lower end of sleeve 73 closely surrounds the lower ends of fingers 68 and causes surfaces 71 thereof to engage beveled surface 67 of running neck 40.

In the locked or operative position illustrated in Fig. 2, the O—rings 34 of the orifice head assembly 31 are in sealing position, and the O-rings 33 of this assembly are also in sealing position, as described hereinabove. Then, flow from the two zones or producing formations takes place independently in the manner previously described, with commingling of the two streams downstream of or above the production zone chokes 37 and 39.

Once the running and locking procedure for the orifice head assembly 31 has been completed in the manner just described, the collet lock 69 can be released only by running a pulling tool (on a wire line) and jarring up on the pulling neck 72 of the orifice head assembly (which moves sleeve 73 upwardly). When this is done, the orifice head assembly 31 can be pulled out of the outer housing 16, which latter remains in position in the hole. Thus, the check valves 23 and 24 (which are secured to outer housing 16, as previously described) remain in position under these circumstances, maintaining separation between the two producing zones at all times (it will be understood that packers 21, 22, and 14, which also remain in position, contribute to this result).

As previously mentioned, a separate test of one zone can be made whenever desired, by blanking off production from the other with a plugged choke bean. It will be remembered that this, with another production test, enables the operator to determine how much each of the two zones contributes to the total flow stream. This test procedure requires two round trips with the orifice head assembly 31. However, the collet lock on the orifice head, the design of the lower end of orifice tube 57, and the design of the running tool, which acts as a centralizer, combine to make this a very simple wire-line operation.

Recapitulating, the tool of this invention offers the major advantages now to be presented. It conserves energy, by allowing the surplus energy from one zone to lift fluid from a weaker zone to the surface; it opens the way for simple, relatively inexpensive concentric duals that can be produced to depletion without the disadvantages of casing-tubing annulus flow; it increases the daily production rate (where one zone is deficient); it increases the total recovery; and, it reduces cost.

The multiple completion tool of this invention (which may be thought of as a dual flow choke, since production from two producing zones or formations takes place through respective chokes, prior to commingling) can be modified for use in single zone completions, that is, in wells producing

from a single zone. In such a case, it would be used as a so-called bottomhole choke, with a single carbide bean (choke bean) contained in the orifice head assembly. In many wells, this would enable elimination of the conventional surface gas heater, and production gains could be made.

Reference should now be had to Fig. 4, which is a view similar to Fig. 2 but illustrating the modified construction. In this figure, elements the same as those of Fig. 2 are denoted by the same reference numerals. In Fig. 4, the landing nipple assembly includes only the landing nipple portion 15a, the ported collar 15b and the polish nipple 15c of Fig. 2 being omitted. In Fig. 4, the landing nipple portion 15a is made somewhat longer than in Fig. 2, and below the "key" recess 47 it is provided with a polished cylindrical wall, to enable a seal to be made by the packing means 22 which is carried by the outer housing 16. The lower end of landing nipple portion 15a is provided with male threads 74 which enable the lower end of this nipple portion to be coupled to the adjacent section of the tubing (not shown). Packing means 22 seals the annulus 18 above threads 74, and prevents the flow of fluid upwardly through such annulus.

The equalizing valve 25 of Fig. 2 is not utilized in Fig. 4, so that in Fig. 4 the lower end of the outer housing 16 opens directly into the interior of the tubing string. Therefore, fluid from the producing formation or zone (which first flows through casing perforations into the casing-tubing annulus and thence into the tubing by way of ports therein or through the lower open end thereof, as previously described in connection with Figs. 1 and 2) flows fro mthe interior of the tubing vertically upward into the lower end of the outer housing 16 of the tool, and thence vertically upward in such housing, through the longitudinal bore therein. Packing means 22 prevents the well fluid from bypassing the desired flow path provided through the bore of outer housing 16.

The landing and locking means for the outer assembly or housing 16 is quite similar to that described in connection with Fig. 2, and operates in an exactly similar manner. The aforesaid means is operated to retrievably lock the outer housing 16 at a predetermined location in the tubing.

In Fig. 4, a construction somewhat different from that of Fig. 2 is used for the orifice head assembly. In Fig. 4, the inner housing or orifice head assembly 31' is again a member separate from outer housing 16, and is retrievably fastened in position in such outer housing. The substantially cylindrical main body portion 55' of orifice head assembly 31' is thickened and the prong-like tubular extension 57 (of Fig. 2) is omitted. The lower end of body portion 55' seats in the running neck 40 of the outer housing 16, and this body portion of the assembly 31' carries a pair of O-rings 33, to provide a seal between the outer surface of this body and the inner wall of the running neck 40 of outer housing 16.

The body portion 55' of orifice head assembly 31' terminates a short distance below the O-rings 33, in a plane substantially in alignment with the lower end of running neck 40, i.e., substantially in alignment with the junction of this running neck and the lower portion of housing 16. The body portion 55' of assembly 31' is provided with a central (axial) longitudinal bore 35 which communicates at its lower end with the longitudinal bore of outer housing 16. Bore 35 provides a fluid flow passage through the body 55' of the orifice head assembly. Fluid from the single producing zone, which flows vertically upward through the longitudinal bore in outer housing 16, flows upwardly in bore or passage 35. Bore 35 extends throughout the entire length of body portion 55' and the upper end of this bore opens into the lower end of a sleeve member 75 which is threadedly secured to the upper end of body 55'. At the upper end of sleeve 75, there is mounted a replaceable choke 37 having a carbide-faced throat 60. Choke 37, through which all of the fluid from the producing zone passes, controls the rate of flow of this fluid. Choke 37, whose throat or passage 60 extends axially of sleeve 75 is held in position at the upper end of sleeve 75 by means of a threaded nut 61, just as in Fig. 2.

The structure for retrievably fastening the orifice head assembly 31' in position in the outer housing 16, i.e., seated in running neck 40 of such outer housing, is exactly the same as has previously been described in connection with Fig. 2, and includes the collet 69, the locking sleeve 73, etc. Such description will not be repeated here.

The bottom-hole choke of Fig. 4 has several advantages, as compared to other chokes of this general category. One of these is the ease of changing the choke means or bean 37. More particularly, running and pulling the orifice head assembly 31' of this invention is faster, more certain, and much simpler than running and pulling the chokebean-carrying mandrels previously used as bottom-hole chokes. To change the choke in prior devices, it is necessary to pull the entire tool; with the tool of this invention, only the orifice head 31' is pulled and reset, the outer housing 16 remaining in position in the hole. The construction of the present invention also substantially eliminates damage to plastic-coated tubing, since nothing which contacts the tubing need be pulled in order to change the choke.

Another advantage of the bottom-hole choke of this invention is its longer life. Since

a much smaller choke bean is used, there can be economically used (at 37) an extremely hard bean, which resists abrasion much better than the larger, softer beans used in conventional devices.

Yet another advantage is that running a conventional bottom-hole choke through liquid creates a problem of liquid bypass, which problem is not present in the Fig. 4 device.

The outer housing 16 in Fig. 4 (as in Fig. 2) has been stated to be a so-called "Otis Type S". However, it can be an "Otis Type J" mandrel or an "Otis Type B" mandrel. The orifice head assembly 31' can be run and locked in all of these mandrels.

WHAT WE CLAIM IS:—

1. A well-flow control device adapted to be positioned in well tubing for controlling the flow of a fluid into the tubing from a producing formation, comprising an outer housing having an opening for communication with the interior of said tubing means carried by the housing for retrievably locking the same at a predetermined location in the tubing, packing means for closing the annular space between the housing and tubing above said opening, said housing having an internal flow channel extending upwardly from its opening; an inner housing having an internal fluid flow passage for communication with said flow channel and with the interior of said tubing above said packing means; means carried by the inner housing for retrievably fastening the same in position in said outer housing, but allowing the withdrawal of the inner housing without the device from the well.

2. A device according to Claim 1 wherein the inner housing provides choke means located in the fluid flow passage.

3. A device according to Claim 2, wherein the choke means is positioned at the top of the inner housing, with the passage of the choke means extending longitudinally of the fluid flow passage.

4. A device according to any of the preceding Claims wherein the choke means is removably secured in said inner housing.

5. A device according to any of the preceding Claims wherein the opening is across the lower end of the outer housing.

6. A device according to any of Claims 1 to 4 wherein the opening in the outer housing is a side port.

7. A device according to Claim 6, wherein the outer housing side port comprises at least one narrow elongated slot in the housing wall, the width dimension of said slot being less than the diameter of the passage in the choke means.

8. A device adapted to be positioned in well tubing for controlling the flow of fluids into the tubing from a plurality of producing formations, comprising an outer housing having a side port for communication with the interior of said tubing; means carried by the housing for retrievably locking the same at a predetermined location in the tubing, packing means for closing the annular space between the housing and tubing above and below said port, said housing having a first internal flow channel extending upwardly from its side port and a second internal flow channel for upward fluid flow from beneath the packing means which is below said port; an inner housing having two internal fluid flow passages for communication respectively with said first and second flow channels, both of said flow passages communicating also with the interior of said tubing above the packing means which is above said port; means carried by the inner housing for retrievably fastening the same in position in said outer housing but allowing the withdrawal of the inner housing without the tool from the well.

9. A device according to Claim 8 wherein the inner housing provides choke means located in at least one of the fluid flow passages.

10. A device according to Claim 9 wherein the choke means or each of them is positioned at the top of the inner housing, with the passage of the choke means or each of them extending longitudinally of the fluid flow passage in which the choke means is located.

11. A device according to Claim 10 wherein the outer housing side port comprises at least one narrow elongated slot in the housing wall, the width dimension of said slot being less than the diameter of the passage of the choke means communicating with said slot.

12. A device according to any of Claims 9 to 11 wherein in the case when choke means are provided in each of the fluid-flow channels of the inner housing, the two choke means are disposed parallel to one another.

13. A device according to Claim 12, wherein the two choke means are separately removably secured in said inner housing.

14. A device according to any of Claims 8 to 13, wherein a resilient check valve member is provided in each of said channels of the iner housing for preventing downward fluid flow therein.

15. A device according to any of Claims 8 to 14, wherein the outer housing has a lower side port located below the packing means which is below the first-mentioned side port, said lower side port communicating with the interior of said tubing and with said second flow channel of the outer housing.

16. A device according to Claim 15, wherein the outer housing lower side ports comprises at least one narrow elongated slot in the housing wall, the width dimension of the slot being less than the diameter of the

passage in any choke means communicating with the slot.

17. A device according to Claim 15 or 16 wherein the annular space between the outer housing and the inner housing above said lower side port is closed by packing means.

18. A flow control device, comprising a main flow control device and an auxiliary flow control device which can be removed from the main flow control device without removing the latter from the well, for a well flow conductor having a longitudinal flow passage and a first lateral port communicating with the flow passage intermediate the ends thereof, the main flow control device including: an elongated mandrel positioned in the well flow conductor and provided with an internal flow passage for communicating at its upper end with the flow passage in the well flow conductor and with a second lateral port intermediate the ends of the mandrel for communicating with the exterior of the mandrel and said internal flow passage and with said first lateral port; seal means carried by the mandrel for sealing between the well flow conductor and the mandrel below said lateral ports, said mandrel having an aperture for communicating with the flow passage of the well flow conductor below the seal means; means carried by the mandrel permitting flow in one direction only into the internal flow passage of the mandrel through said second lateral port and said aperture; the auxiliary flow control device being releasably securable to the upper end of the mandrel and having means extending into the said internal flow passage providing with said internal flow passage, when the auxiliary flow control device is secured to the main flow control device, a first flow passage communicating with said second lateral port of the mandrel and opening upwardly into the well flow conductor above said first lateral port and providing a second flow passage communicating with said aperture and opening upwardly into the well flow conductor.

19. A main flow control device according to Claim 18 wherein seal means is provided on said mandrel for sealing between the mandrel and the well flow conductor above said ports.

20. A main flow control device according to Claim 19 wherein means are carried by the mandrel for releasably securing the mandrel in the well flow conductor and wherein the auxiliary flow control device has means in each of said first and second flow passages providing restricted orifices of predetermined relative sizes.

21. A main flow control device, according to Claim 20 wherein said auxiliary flow control device comprises a tube extension telescopable into said mandrel and having its lower end communicating with the aperture of the mandrel.

22. A main flow control device, according to Claim 21 wherein seal means are provided between the mandrel and the tube extension disposed between said second lateral port and the aperture of the mandrel.

23. A main flow control device, according to any of Claims 18 to 22 wherein the mandrel is provided with a downwardly facing shoulder at the upper end thereof, the auxiliary flow control device having means for engaging the downwardly facing shoulder to releasably secure the auxiliary flow control device to the mandrel.

24. A main flow control device according to Claim 23 wherein a lock means is provided on the auxiliary flow control device for holding the releasable means against disengagement from the downwardly facing shoulder.

25. A main flow control device according to any of Claims 21 to 24 wherein said auxiliary flow control device has a body provided with a pair of upwardly opening flow passages, one of said passages communicating with said second lateral port; and the other of said passages of the body communicating with said aperture.

26. A flow control device substantially as herein described with reference to Figures 1, 2A, 2B, 2C, 2D, and 3 or Figures 4A, 4B, 4C, and 4D of the accompanying drawings.

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London, W.C.2.
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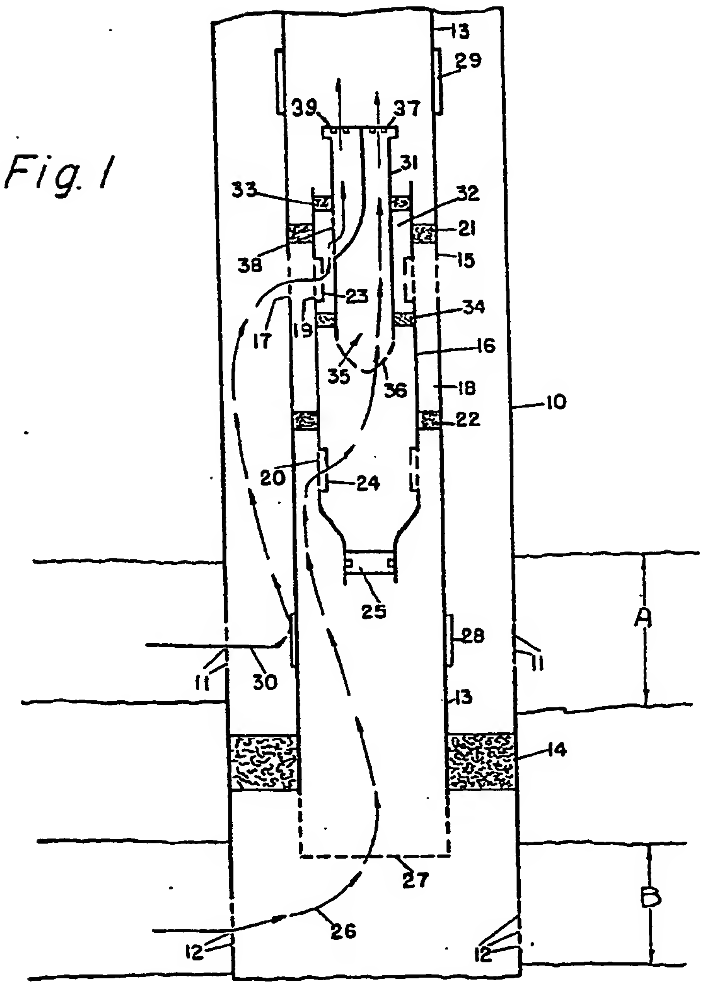
Fig. 1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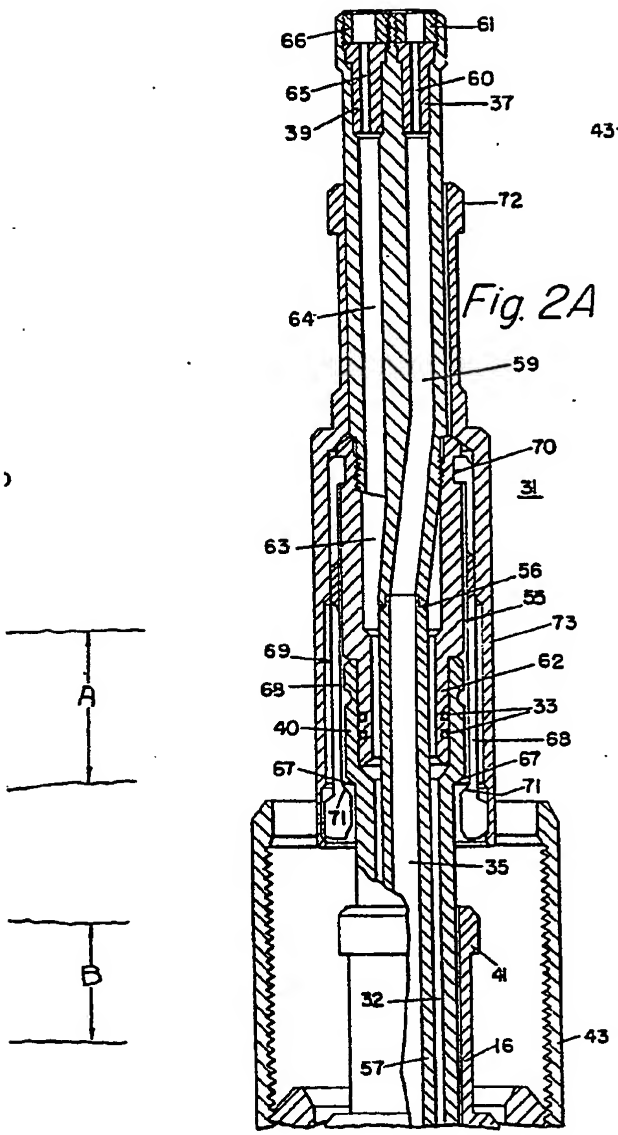

Fig. 2A

Fig. 2B

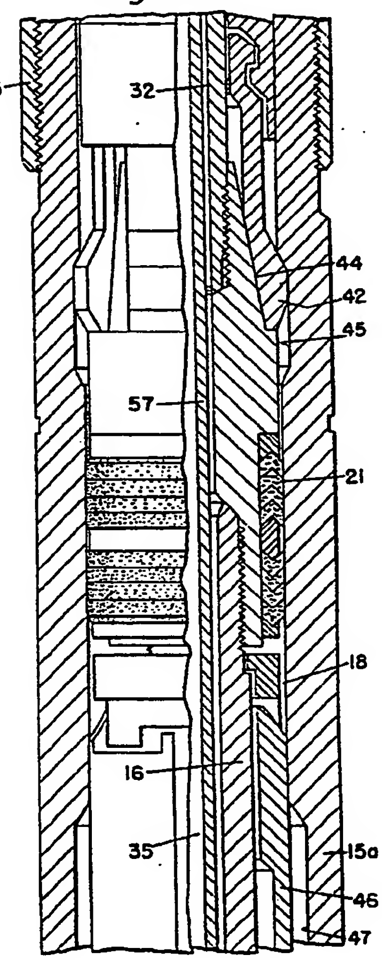

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Fig. 1

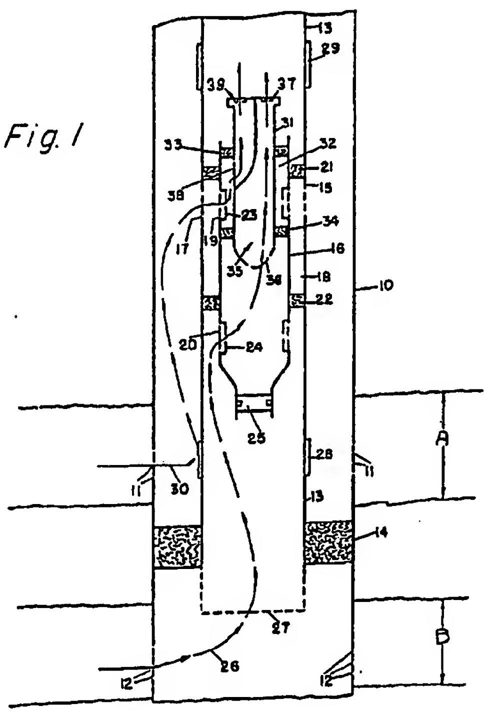


Fig. 2A

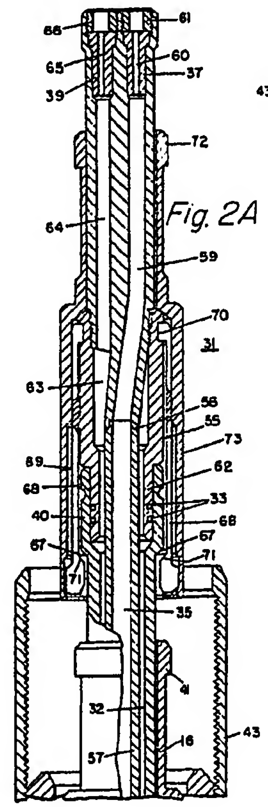
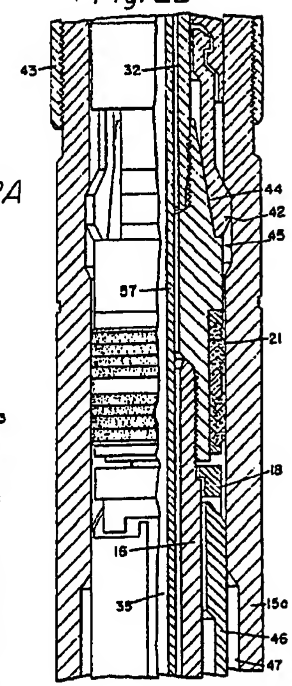


Fig. 2B



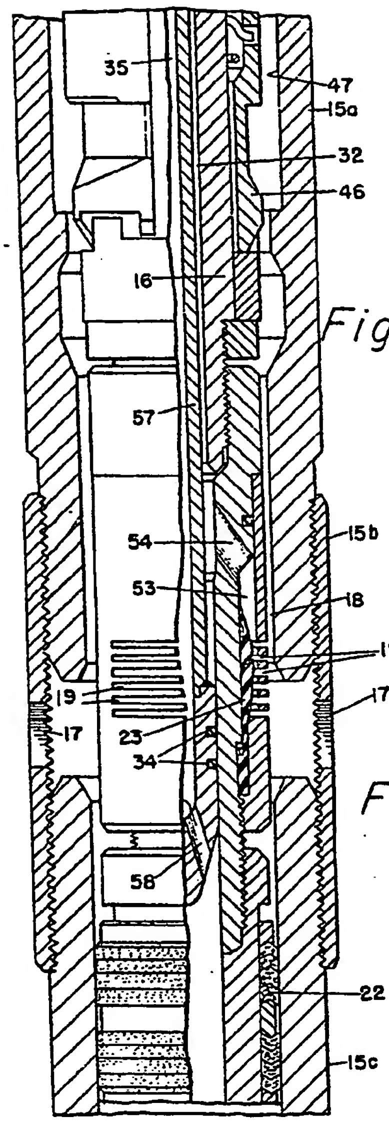


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Fig.2C

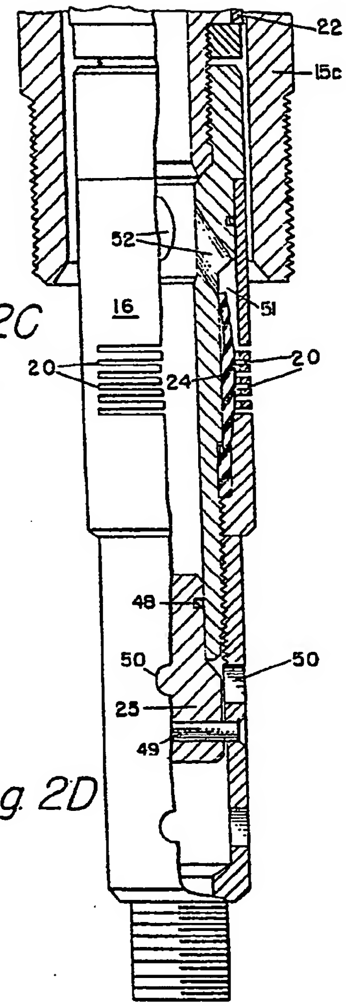

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Fig. 2D

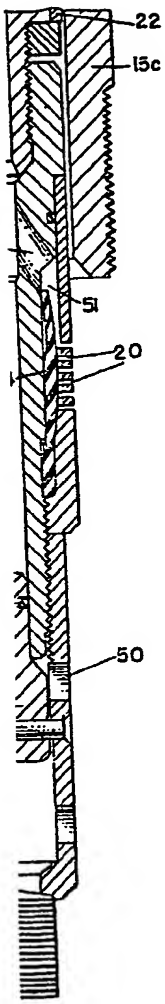
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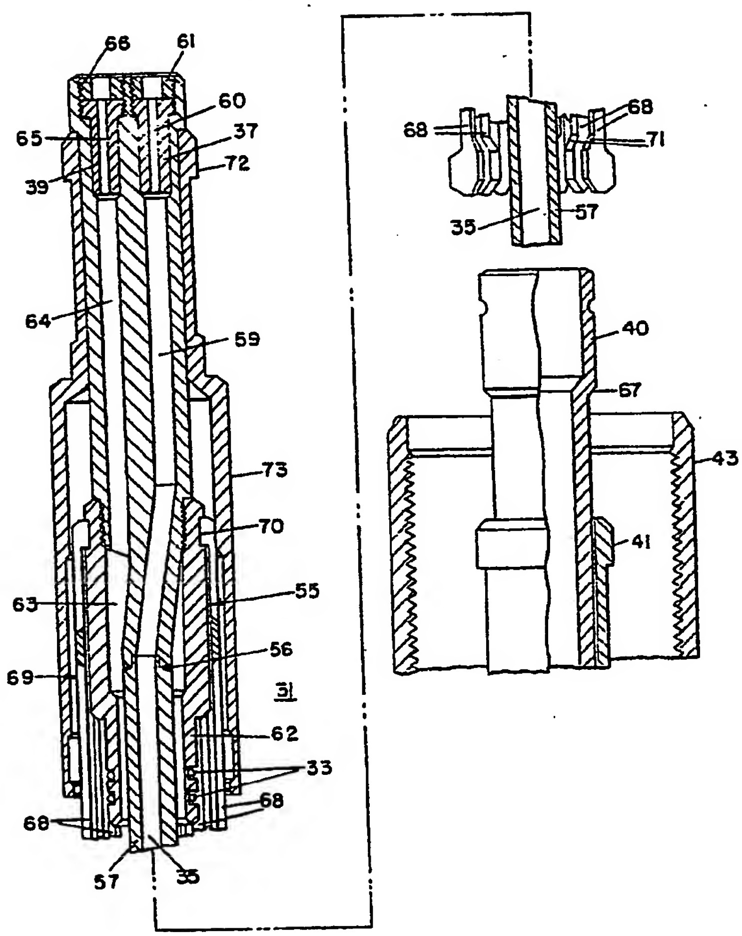
Fig. 3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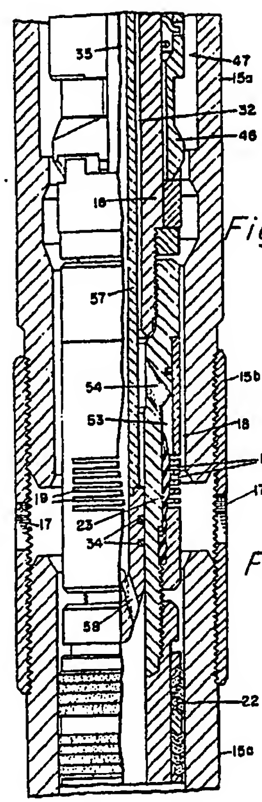

Fig.2C

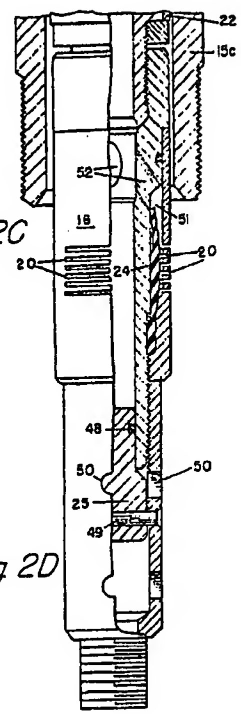

Fig.2D

Fig. 3

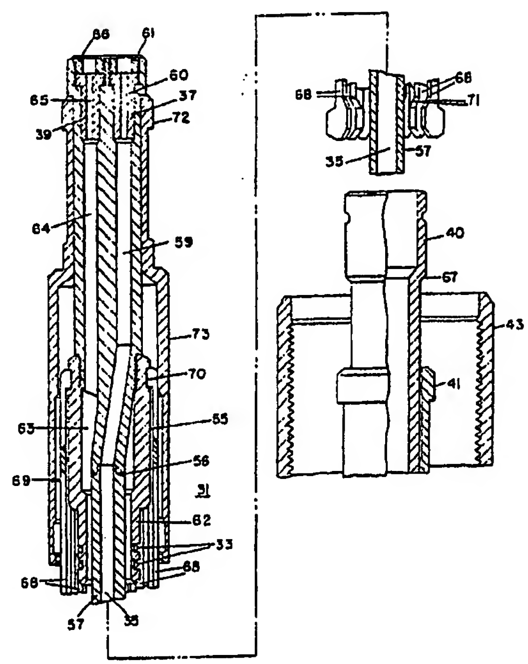

Fig. 4A

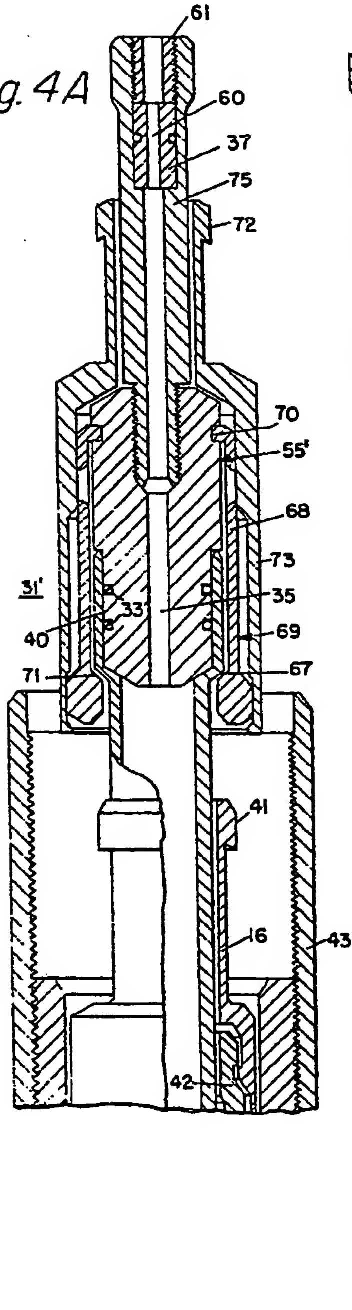
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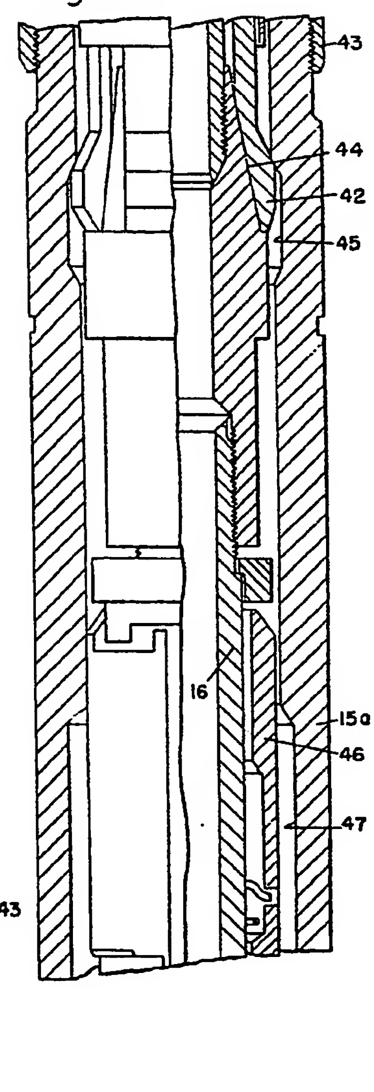
Fig. 4B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can be utilized to effect or aid the flow from at least one of the other zones. Production can be secured from any desired number of formations simultaneously, even though flow from some of them normally would not be obtained from a single completion well in such formation.

The invention is more specifically described with reference to the accompanying drawings in which:

Fig. 1 is a simplified cross-sectional view of a well in which one type of the flow control device has been used for completing the well to produce from an upper zone through ports in the tube and from a lower zone through the bottom end of the tubing.

Figs. 2—A and 2—B, taken together, constitute Fig. 2 which is an elevational cross-sectional view illustrating in detail a form of flow control device.

Figs. 3, 4, 5 and 6 are cross-sectional views of the device of Fig. 2 taken on the lines 3—3, 4—4, 5—5 and 6—6, respectively.

Fig. 7 is a schematic illustration of a well traversing two production zones and in which another form of flow control device is employed.

Fig. 8 is an elevational cross-sectional view illustrating in more detail the flow control device shown in Fig. 7.

Fig. 9 is a schematic illustration of a well traversing two production zones the upper of which has insufficient pressure to permit flow into the well tubing and which has been provided with means for intermittently forcing oil from the upper zone into the tubing.

Fig. 10 is a schematic illustration of a well completed for production from two zones in which means are provided for introducing gas from the surface to aid in lifting the mixed streams of oil in the tubing.

Referring now to Fig. 1, a well is shown which has a casing 10 which has been cemented in place in the usual manner by cement body 11. The well traverses two production zones, illustrated as Zones A and B, which may be either gas or oil formations. The casing has been perforated for production from both zones, as illustrated by perforations 12 adjacent upper Zone A and perforations 13 adjacent lower Zone B. A tubing string 14 is positioned in the casing and the annulus therebetween is closed off near the bottom of the tubing by means of packer 9. The tubing carries a landing nipple 15 adapted to receive the flow control device which is held in position by means of conventional latches 16 provided at the top of the device. The landing nipple is positioned adjacent Zone A and contains ports 17 for receiving fluid from the formation.

The flow control device, which is positioned in the landing nipple in conventional manner by means of a wire line, comprises a cylindrical housing 18 which forms an annulus 19 with the landing nipple, and which contains ports 20 for passage of fluid from Zone A. Packing means 21 positioned above and below the ports 17 and 20 prevent fluid flow along the annulus 19 and require the fluid to flow through perforations 20 in the housing. The housing contains a baffle member 34 which forms an annular upwardly extending flow channel 22 that leads to a port 23 in transverse baffle 24. A resilient check valve member having a circular edge 25 is provided in flow channel 22 to prevent backflow of fluid toward Zone A. Any downward flow of fluid from port 23 causes edge 25 of the valve to move outwardly against the edge of the housing wall at 26 and close the annular channel, thus preventing downward flow. The check valve should be constructed of a tough material, such as neoprene, which is unaffected by well fluids and which has sufficient flexibility for movement of the edge 25 against the valve seat 26.

The transverse baffle 24 contains a second port 27 which is threaded for receiving a choke 28 that serves to regulate the flow from the lower Zone B. Port 23 also may be threaded for receiving a choke (not shown) in cases where the pressure in Zone A is high. Baffle 24 has a cylindrical extension 29 positioned inside baffle 34 and "O" rings 30 are provided for sealing the annulus therebetween. Extension 29 thus forms a passageway leading to port 27 and choke 28.

In a lower part of housing 18 another baffle 31 is positioned to form an annular flow channel 32, and another resilient check valve 33 is provided in the channel to prevent backflow of fluid toward the lower Zone B.

It may be seen that the device as above described provides two separate flow channels for the fluids from the two formations, which channels terminate adjacent each other in the well tubing at which point the flowing fluids mix with each other. The device also has the important feature of providing throttling means (i.e., one or more chokes) for reducing the pressure of either or both fluids prior to their admixing. It further includes means for preventing backflow to either formation so that fluid from one formation in no case can flow to and enter the other formation.

For the purpose of illustrating advantages of the present invention, assume that Zone B of Fig. 1 is a high pressure oil zone but that Zone A has a pressure which is too low to overcome the hydrostatic head in the well and hence would not normally flow. The device of Fig. 1 can be employed so as to utilize the fluid flow from Zone B to cause flow from Zone A. A choke 28 having an opening of appropriate size to secure the allowable rate of flow from the lower zone is placed in port 27. Flow from the lower formation is then begun. The sharp pressure reduction resulting from passage of the fluid through choke 28 causes fluid from the low pressure zone to flow through the control device and issue from

port 23. The two streams then mix and the mixture flows upwardly in the tubing. When Zone B is an oil formation, the sharp pressure drop at the choke causes solution gas to be released and the released gas and any free gas already present in the oil stream provides a lifting action which aids the flow of the mixed streams. When Zone B is a gas formation, lifting of oil from Zone A likewise is effected. Control of the rate of flow from the upper zone can best be achieved by regulating the pressure of the flowing stream at the well head, which generally can be done without substantially affecting the flow rate from the high pressure formation. Alternatively, control of the rate of flow from the upper zone can be effected by means of a choke of appropriate throat size in port 23.

By employing the device in the foregoing manner, production can be accomplished from a "dead" zone, i.e., a zone which has insufficient pressure normally to overcome the hydrostatic head of the column of fluid in the well. The "dead" zone can be either the upper or lower zone and the device will work equally as well; provided that when it is the lower zone, it much have enough pressure to permit its fluid to rise to the level of the control device.

In one particularly useful embodiment of the invention, a gas sand penetrated by a "dead" well, which initially was a single completion well in an oil zone, can be utilized to flow oil from the oil zone. One or more gas sands commonly are available in single completion oil wells. When the reservoir pressure has dropped enough that the desired rate of oil flow cannot be maintained, a control device such as that shown in Fig. 1 can be placed in the well to obtain a flow of gas from the gas sand into the well tubing. The gas sand can be one which is either above or below the oil sand. Gas can be admitted to the tubing through a choke of the proper size to obtain a gas rate that will effect the desired lifting action on the oil column. Thus energy derived from the gas reservoir can be utilized to secure the desired rate of flow from the "dead" oil formation.

Referring now to Figs. 2—6, a more detailed form of flow control device is shown which is adapted to be anchored in a conventional landing nipple as described in connection with Fig. 1. The device is landed in a nipple 40 having side ports 41 for entrance of well fluid from the formation adjacent to which the device is anchored. An elongated assembly 46, which projects through the bottom of nipple 40 as shown at 42, provides a channel for upward flow of fluid entering side ports 41 and a separate channel for flow of fluid from one or more lower production zones which fluid enters through longitudinal ports 43 at the bottom. Packing members 48 are provided above and below side ports 41 to seal off the annulus between landing nipple 40 and assembly 46.

Ports 43 at the bottom lead to a single flow zone 44 in which is positioned a resilient check valve member 45 adapted to prevent downward flow of fluid. Above flow zone 44 a replaceable choke 49 having throat 50 is positioned for controlling the rate of flow of fluid derived from the lower formation. From the choke 49 the flow channel leads through central channel 51 and offset channel 52 which leads to a common passageway 53.

The separate flow channel for the fluid entering through side ports 41 includes ports 54 in the side of assembly 46, an annular channel 55 therein and a communicating longitudinal channel 56 which terminates at the common passageway 53 leading to the upper part of the well tubing. The end of channel 56 is threaded, as indicated at 57, to receive a choke (not shown) in case it should be desirable to control the flow rate of the stream at this point. A resilient check valve member 58 is positioned in annular channel 55 to prevent backflow of fluid through side ports 41.

Conventional latching means, indicated generally as 59, are provided at the top of the device shown in Fig. 2 for securing it in its landing nipple in a tubing string. This device functions in essentially the same manner as described in connection with Fig. 1. One or more of such devices can be used at appropriate locations in the well tubing for regulating or effecting flow from a plurality of formations containing oil and/or gas.

Referring now to Fig. 7, a section of a well is indicated in which two devices of another form adapted to be seated in a side pocket mandrel are utilized for controlling the flow from two separate production zones located above one or more lower zones. The well includes a perforated casing 60 passing through Zones A and B and a tubing string 61 inside the casing. Adjacent the upper zone a side pocket mandrel 62 is positioned in the tubing string, and another side pocket mandrel 62^1 is likewise positioned adjacent the lower zone. Flow control tools 64 and 64^1 of the type shown in detail in Fig. 8 are positioned in the side pockets of the mandrels. The side pocket of each mandrel and the side of each tool are provided with cooperating ports for flow of the formation fluids. Tools 64 and 64^1 have internal channels leading to choke ports through which the fluid passes to the tubing string. Flow occurs in the manner indicated by arrows in Fig. 7. This well assembly arrangement can be employed in the same manner as that of Fig. 1 for utilizing a gas sand to effect oil flow from a "dead" zone.

While only two producing zones have been shown in Fig. 7, it should be understood that this arrangement can be used for any desired number of such zones. A control tool for each zone can be lowered in the well on a wire line and set in place by means of a kick-over device

known in the art. By having the tools placed in the mandrel side pockets, the tubing string remains open and a wire line can be run to any desired depth without any necessity for previously removing tools placed above such depth. This is advantageous since it allows any tool to be pulled from the well without disturbing any of the others. Thus any one of the production zones can be selectively acidized, chemically treated or fractured without affecting any of the other zones. For example, if it is desired to acidize Zone B, control tool 64[1] would be removed and acid would be pumped down the tubing and into the formation through the ports in the mandrel and casing. The check valve 72 (Fig. 8) in control tool 64 would prevent acid from reaching Zone A. Likewise any desired formation can be selectively worked over or treated for sand control without removing the well tubing and without the possibility of damaging any other formation by introducing drilling mud into the well as done in conventional practice.

Fig. 8 illustrates tool 64 and mandrel 62 in more detail. The mandrel contains a cylindrical side pocket 63 a portion of the left-hand edge of which merges into and is actually integral with the mandrel wall. The mandrel contains perforations 65 for admission of the formation fluid. Tool 64 comprises a housing 66 having side ports 67 in fluid communication with the mandrel perforations. At the upper part of the housing latch means 68 and a pulling head 69, each of conventional design, are provided. Sealing means 70 are provided above and below perforations 67 for sealing the annular space between the mandrel side pocket 63 and housing 66. The housing provides a downflow channel 71 in which is positioned resilient check valve member 72 to prevent backflow toward the formation. The channel terminates at the bottom of the tool in a choke 73 having throat 74 through which the formation fluid issues into the tubing string.

Referring back to Fig. 7, assume that Zone A is a high pressure oil zone and that Zone B is an oil zone having a low pressure such that it would not normally flow from a single completion well. The pressure of Zone B, however, is sufficient to lift its fluid to the level of Zone A. It is assumed in this instance that the well tubing is plugged off beneath Zone B. The arrangement shown in Fig. 7 will permit production of oil from Zone B in addition to Zone A. Flow of the Zone A oil through the choke in the bottom of the upper control tool results in a reduced pressure in the tubing at this point. Some of the gas in solution in the Zone A oil prior to reducing its pressure will come out of solution and thus aid in lifting the Zone B oil to the top of the well. Thus a mixed stream of oil from the two zones can be withdrawn at the well head. By having the proper choke size in the control tool adjacent Zone A, production from this zone at the desired or allowable rate can be obtained. The rate of flow from the lower zone can readily be regulated by appropriately setting the pressure in line 75 at the well head by means of back pressure valve 76. Alternatively, such rate can be controlled by having a choke of the proper size in the control tool adjacent the lower zone.

The following is a specific illustration of an embodiment of the present invention as it would be applied to a well which penetrated two oil sands at depths of 8536—8544 and 8626—8629 feet, respectively. The well had originally been dually completed in conventional manner for production from the upper zone through the annulus and from the lower zone through the tubing. The allowable production rates for the upper and lower zones were, respectively, 30 and 7 barrels per day. After producing in this manner for a period, the well ceased to flow from the upper zone, due to a drop in its pressure. At that time the static bottom hole pressure for the upper zone was 2295 p.s.i.g. while the static and flowing bottom hole pressures for the lower zone were 3577 and 3551 p.s.i.g.

The present invention can be applied to the above described well in the following manner to obtain production from the upper zone. In the perforated landing nipple in the tubing adjacent the upper zone a control device of the type shown in Fig. 2 is located. The device contains a choke of the appropriate size for maintaining the rate of flow from the lower zone at 7 barrels per day. A back pressure regulator, such as shown in Fig. 7, is provided in the flow line from the well tubing to control the rate of production from the upper zone. Varying the back pressure at the surface by means of the regulator will cause the flow rates from the two zones generally to approximate the following values:

Surface pressure, p.s.i.g.	Rates, bbls. per day Lower Zone	Upper Zone
0	7	84
100	7	84
470	7	84
600	7	73
900	7	51
1200	7	29
1500	7	7
1600	7	0
2500	5½	0

Thus, by regulating the pressure at the surface to a value slightly less than 1200 p.s.i.g., the allowable production rates can readily be maintained. As production in this manner continues and the formation pressures drop, the desired rates of production can be maintained by decreasing the surface pressure by means of the regulator.

Fig. 9 illustrates a well which has been dually completed in Zones A and B in the manner of the present invention and which is provided with means for admitting extraneous gas under pressure to the annulus between the casing 80 and the well tubing 81. The annulus is sealed between the two zones by means of a packer 82 and the tubing string contains a control device, shown generally at 83, such as the device shown in detail in Figs. 2—6. Zone A is a "dead" zone which has sufficient pressure to cause the liquid to rise in the annulus to the level shown at 84 but insufficient to force the liquid through the control device into the well tubing. At the well head a gas supply line 85 is provided with a time controlled gas injecting and venting device 86. This device alternately admits gas under pressure into the annulus and then vents the gas through line 87. This causes an intermittent pumping of the oil from the annulus through control device 83 into the tubing. The fluid from high pressure Zone B then serves as the means for flowing the annulus oil to the surface. Upon passing through the choke provided in control device 83, the Zone B oil releases solution gas and the released gas aids in lifting the mixed oil streams through the tubing to the well head.

Fig. 10 illustrates a well completed for production from oil Zones A and B and provided with gas lifting means employing extraneous gas. This assembly can be utilized in cases where the well does not pass through a gas sand and neither zone has sufficient pressure to make a flowing well. The well comprises a casing 90 perforated adjacent Zones A and B, a tubing string 91 carrying a control device 92 such as that shown in Figs. 2—6, a packer 93 between Zones A and B and preferably a packer 94 above the upper zone although the latter packer is not essential. The tubing string has a side pocket mandrel 95 above the upper packer which is adapted to carry in its side pocket a device 96 for admitting gas to the tubing. The mandrel contains a port through which gas can pass to the device 96. This device can be a flow control device of the type described in connection with Fig. 8, with the choke port 74 being sized to admit gas at the desired rate to the tubing. Alternatively, device 96 of Fig. 10 can be a conventional gas injection valve which is set to open when the gas pressure in the annulus reaches a predetermined value. Gas is admitted to the top of the annulus through conduit 97 under sufficient pressure to give the desired injection rate into the tubing. This effects lifting of the mixed oil stream flowing upwardly from the control device 92 and allows the mixture to flow from the well. In cases where the well tubing may tend to load up with salt water, additional side pocket mandrels (not shown) can be provided at higher levels in the tubing string. This would permit unloading from a higher level and thus avoid having to apply too high a gas pressure within the casing. Such mandrels normally would contain dummy valves any of which could be replaced by a gas injection device 96 on a wire line whenever it became desirable to gas lift from a higher level.

The control devices described herein for effecting multiple completion of wells for simultaneous flow through the well tubing offer many advantages over conventional oil field practice. Well assemblies provided in accordance with the invention avoid the danger of corrosion and erosion of the casing or eliminate the disadvantages of multiple tubing strings requiring specialized packers and well head equipment. The invention permits efficient simultaneous depletion of any number of production formations through a single string of tubing. In conventional practice where choking of the separate streams from a multiple completion well is done at the surface, plugging of the chokes often occurs due to paraffin deposition or formation of gas hydrates. This is avoided by the use of the present invention, since the streams are choked within the control device adjacent the producing formation where the temperature is elevated so that neither paraffin deposition nor hydrate formation will

occur. Numerous other advantages derived from the present invention will be apparent to persons skilled in the art.

WHAT WE CLAIM IS:—

1. A device adapted to be positioned in well tubing adjacent an inlet port therein for controlling flow of fluids into the tubing from a plurality of formations which comprises a housing having a side port for communication with said inlet port, means carried by the housing for retrievably locking the device adjacent said inlet port in the tubing, packing means for closing the annular space between the housing and tubing above and below said ports, said housing having an internal flow channel extending upwardly from its side port and a separate internal flow channel for upward fluid flow from beneath the device, each of said channels communicating with a common fluid passageway leading to the well tubing, a resilient check valve member in each of said channels for preventing downward fluid flow therein, and choke means in at least one of said channels for reducing the pressure of fluid flowing therethrough.

2. A well flowing assembly for flow of fluids from a plurality of production formations which assembly comprises a well tubing having a side pocket mandrel adjacent an upper formation, said mandrel having a port for flow of formation fluid into its side pocket, a housing positioned in the side pocket and having a side port and a communicating internal flow channel extending through the housing, packing means between the side pocket and the housing above and below said ports, a resilient check valve member in said channel for preventing backflow of fluid toward the formation, a choke in said channel, and a second resilient check valve member in the well tubing beneath said mandrel for preventing backflow of fluid toward a lower formation.

3. A well flowing assembly for flow of fluids from a plurality of production formations which assembly comprises a well tubing having a side pocket mandrel adjacent an upper formation and another side pocket mandrel adjacent a lower formation, each of said mandrels having a port for entrance of formation fluid into its side pocket, a housing positioned in each of said side pockets and having a side port and a communicating internal flow channel extending through the housing, packing means between each side pocket and housing above and below said ports, a resilient check valve member in each of said channels for preventing backflow of fluid to a formation, and a choke in at least one of said channels.

4. Method of producing a well which has been completed for production from a plurality of zones containing fluids under different pressures, said well having a well tubing containing entrance ports adjacent all of the zones, which comprises providing within the well tubing a flow channel for fluid from a zone of relatively high pressure and a separate flow channel for fluid from a zone of relatively low pressure, said channels communicating with a common fluid passageway, flowing a stream of fluid from the zone of high pressure toward said common passageway, reducing the pressure of the fluid ahead of said passageway to a value less than that of the low pressure zone, whereby a stream of fluid is caused to flow from such low pressure zone toward said common passageway, mixing said streams in the common passageway and withdrawing the mixture from the well.

5. Method according to Claim 4 additionally comprising controlling the rate of flow from the low pressure zone by regulating the flowing pressure of said mixture at the locus of withdrawal from the well.

6. Method of producing a well traversing two oil zones one of which has sufficient pressure normally to flow from the well and the other of which has insufficient pressure normally to permit the desired rate of flow therefrom, said well having a well tubing containing entrance ports adjacent both zones, which comprises providing within the well tubing a flow channel from one of said zones and a separate flow channel from the other, said flow channels communicating with a common fluid passageway adjacent the upper zone, flowing oil from the high pressure zone toward said common passageway, reducing the pressure of the flowing oil ahead of such passageway to a value less than that of the low pressure zone, whereby solution gas is released from liquid phase, flowing oil from the low pressure zone into said passageway and therein admixing the same with the fluid from the high pressure zone, and utilizing the lifting action of the released gas to flow the mixture up the tubing and from the well.

7. Method according to Claim 6 additionally comprising controlling the rate of flow from the low pressure zone by regulating the flowing pressure of said mixture at the locus of withdrawal from the well.

8. Method of producing a well traversing a high pressure gas zone and an oil zone which has insufficient pressure normally to permit the desired rate of flow therefrom, said well having a well tubing containing entrance ports adjacent both zones, which comprises providing within the well tubing a flow channel from one of said zones and a separate flow channel from the other, said flow channels communicating with a common fluid passageway adjacent the upper zone, flowing gas from the gas zone toward said common passageway, reducing the pressure of the gas ahead of such passageway to a value less than that of the low pressure zone, whereby oil flows from the oil zone into said passageway, and utilizing the lifting action of the gas to flow the oil up the tubing and from the well.

9. Method for producing a well from an

upper zone having a pressure insufficient to permit the desired rate of fluid flow therefrom and a lower zone of high pressure in a cased well having a packer positioned between the two zones in the annulus between the casing and well tubing and having an entrance port in the tubing adjacent the upper zone which method comprises providing a one-way channel from said port to a common fluid passageway in the tubing, flowing fluid from the lower zone up the tubing toward said common passageway, throttling such flowing fluid ahead of said passageway to regulate its rate of flow, whereby the pressure of such fluid is reduced to a value intermediate the pressures of said zone, alternatively introducing and withdrawing gas under pressure to the top of said annulus, whereby fluid in said annulus from the upper formation is intermittently forced through said one-way channel into said common passageway, and withdrawing the resulting fluid mixture from the top of the tubing.

10. A well assembly for producing a well from an upper zone of low pressure and from a lower zone of high pressure which comprises a casing perforated to permit flow from said zones, a well tubing within the casing having a flow port adjacent the upper zone, a packer positioned between the two zones in the annulus between the casing and tubing, means in the tubing adjacent the upper zone providing a one-way channel from said flow port to a common fluid passageway in the tubing, means in the tubing providing a separate channel for fluid flow from the lower zone to said common passageway, means for reducing the pressure of the fluid from the lower zone ahead of the passageway, and means for alternately introducing and withdrawing gas into the top of said annulus to intermittently force fluid from the annulus through said flow port.

11. Method of producing a well from two zones having different pressures each insufficient to cause flow from the well at the desired rate, said well having a casing perforated at each of said zones and a tubing containing entrance ports adjacent each of the zones, which comprises providing within the well tubing a flow channel for fluid from one of the zones and a separate flow channel for fluid from the other zone, said channels communicating with a common fluid passageway, flowing fluid from the zone of higher pressure toward said common passageway, reducing the pressure of the fluid ahead of said passageway to a value less than that of the low pressure zone, whereby a stream of fluid is caused to flow from such low pressure zone toward said common passageway, mixing said streams in the common passageway and flowing the mixture upwardly in the tubing, introducing gas in the annulus between the casing and tubing and injecting the same into said mixture in the tubing, thereby lifting the mixture up the tubing and from the well.

12. A well flowing assembly for producing a well from two zones having different pressures which comprises a casing perforated at said zones, a tubing within the casing containing entrance ports adjacent said zones, means within the tubing forming separate flow channels from said entrance ports leading to a common fluid passageway, resilient check valve means in each of said channels to prevent backflow to the formations, and means for throttling the fluid in the channel from the formation of higher pressure ahead of said passageway to reduce its pressure to a value lower than that of the lower pressure formation.

13. A well flowing assembly for producing a well from two zones having different pressures each insufficient to cause flow from the well at the desired rate which comprises a casing perforated at said zones, a tubing within the casing containing entrance ports adjacent said zones, means within the tubing forming separate flow channels from said entrance ports leading to a common fluid passageway, resilient check valve means in each of said channels to prevent backflow to the formations, means for throttling the fluid in the channel from the formation of higher pressure ahead of said passageway to reduce its pressure to a value lower than that of the lower pressure formation, means for introducing gas under pressure into the annulus between the tubing and casing, and means for injecting such gas into the tubing above said separate flow channels.

14. A device adapted to be positioned in well tubing adjacent a side inlet port therein for controlling flow of fluids into the tubing from a plurality of formations which comprises a housing, means carried by the housing for retrievably locking the device adjacent said inlet port in the tubing, packing means for closing the annular space between the housing and tubing above and below said inlet port, a port in the housing adapted to cooperate with said tubing port to permit fluid flow from a formation, baffle means within the housing forming a flow channel extending upwardly from said housing port and a separate flow channel for fluid flowing upwardly from beneath the housing, said channels terminating in choke ports positioned adjacent to each other, and resilient check valve means positioned in each of said channels to prevent downward flow therein.

15. A device adapted to be positioned in well tubing adjacent an inlet port therein for controlling flow of fluids into the tubing from a plurality of formations constructed and arranged to operate substantially as herein described with reference to Figure 1 or Figures 2A, 2B and 3—6, or Figures 7 and 8, or Figure 9 or Figure 10 of the accompanying drawings.

16. A method of producing a well which

has been completed for production from a plurality of zones containing fluids under difference pressures substantially as herein described with references to Figure 1 or Figures 2A, 2B and 3—6, or Figures 7 and 8, or Figure 9 or Figure 10 of the accompanying drawings.

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Agents for the Applicants.

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851,096 COMPLETE SPECIFICATION
5 SHEETS

This drawing is a reproduction of the Original on a reduced scale.
SHEET 1

Fig. 1

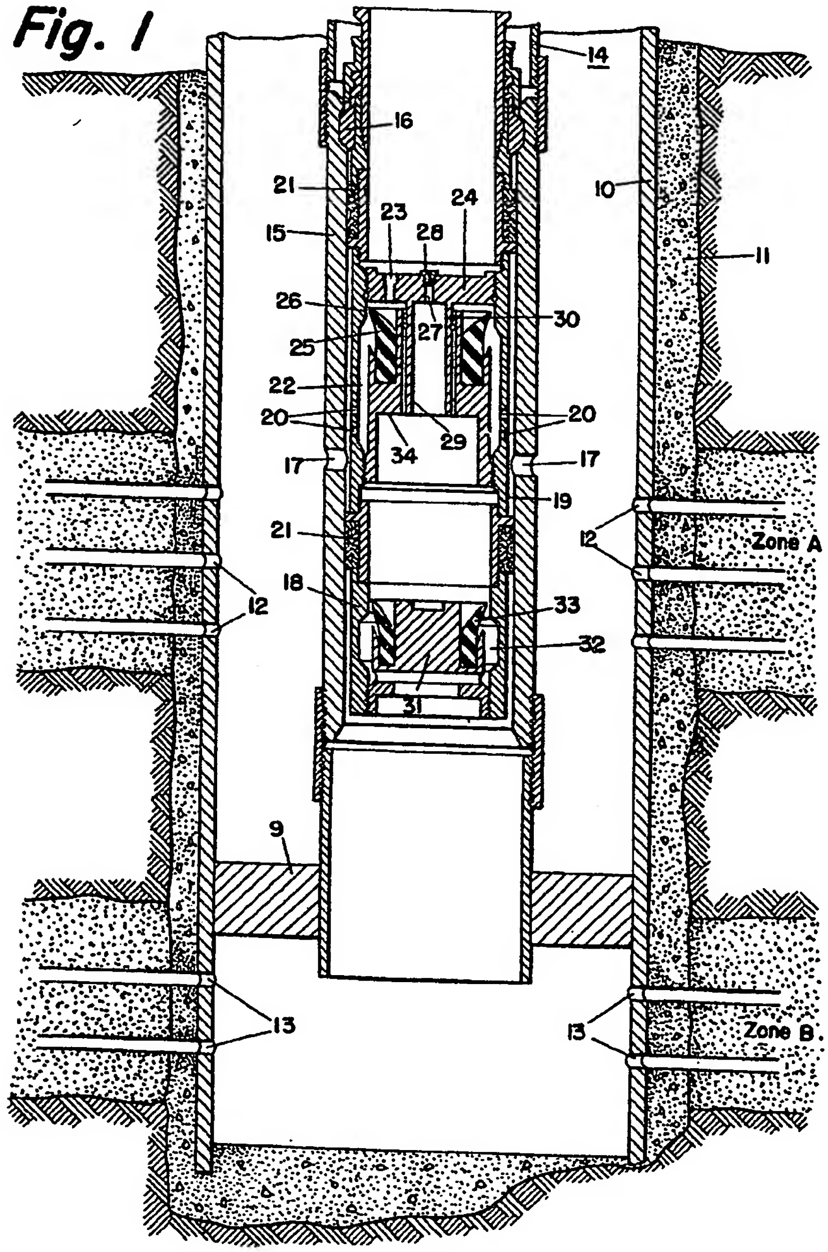

Fig. 2A

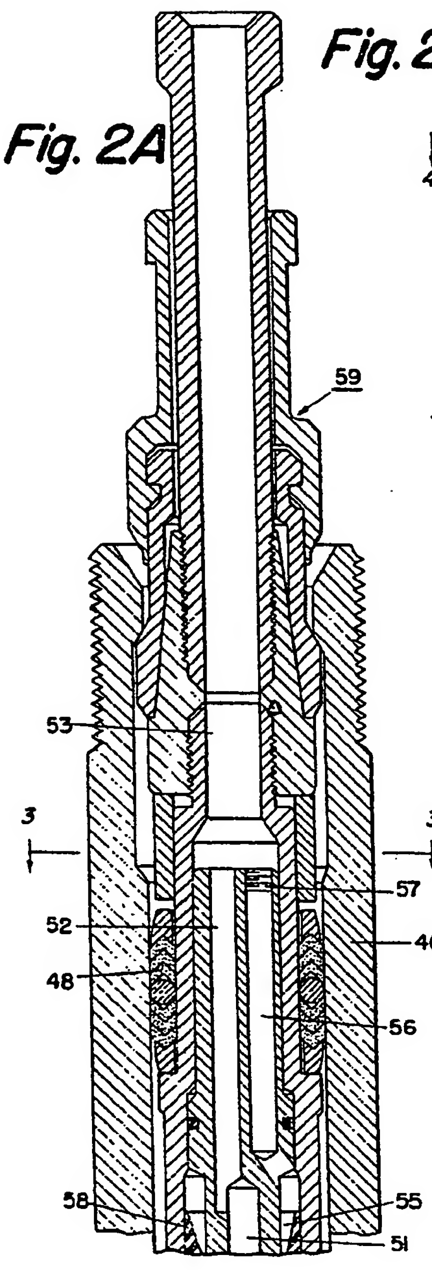
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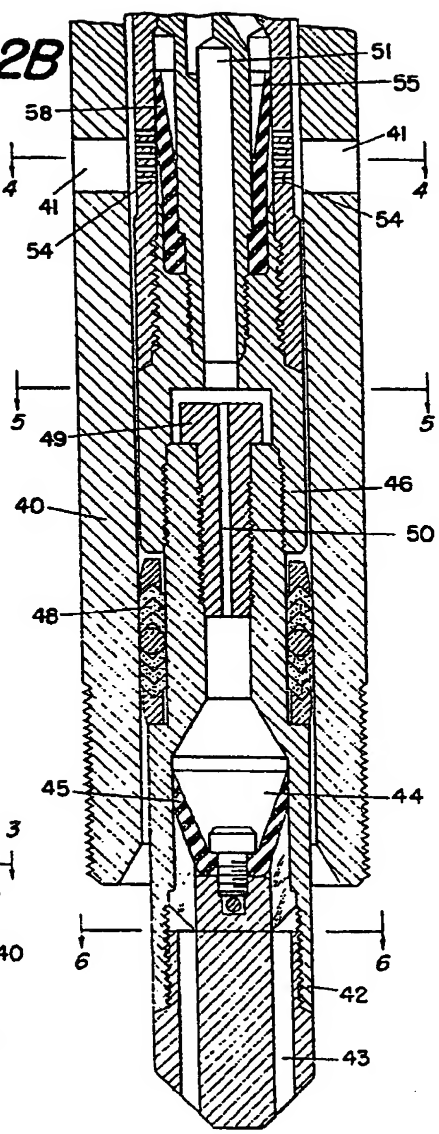
Fig. 2B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851,096 COMPLETE SPECIFICATION
5 SHEETS

This drawing is a reproduction of the Original on a reduced scale.
SHEETS 2 & 3

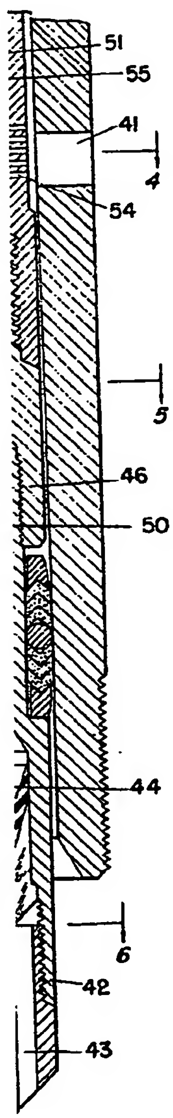


Fig. 3

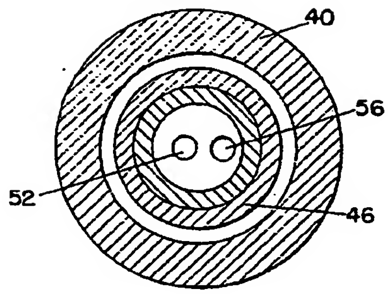


Fig. 4

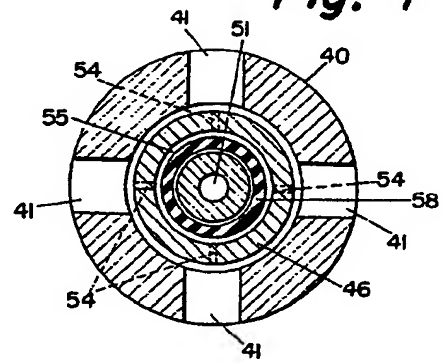


Fig. 5

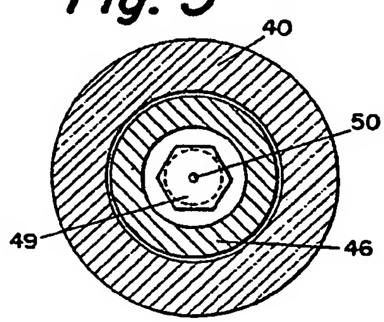
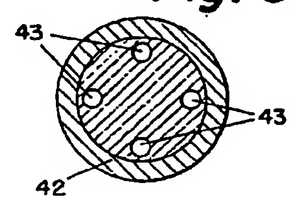


Fig. 6



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5 SHEETS This drawing is a reproduction of the Original on a reduced scale.
SHEETS 2 & 3

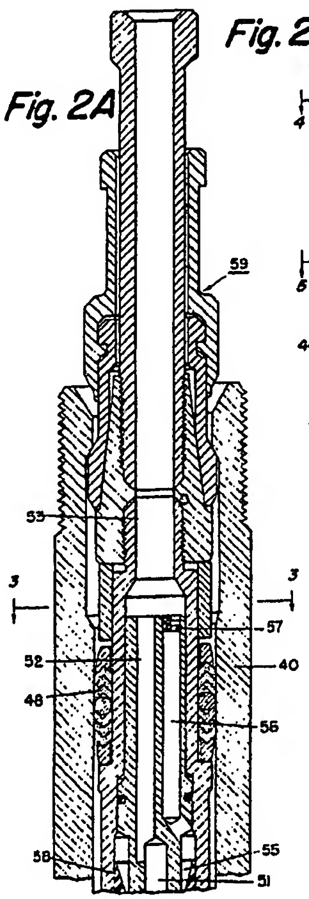


Fig. 2A

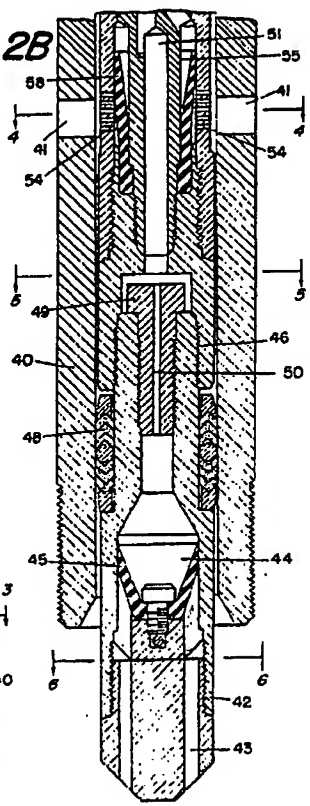


Fig. 2B

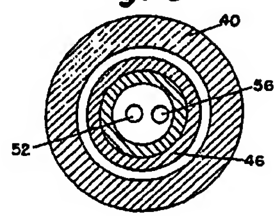


Fig. 3

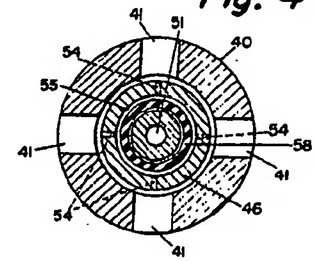


Fig. 4

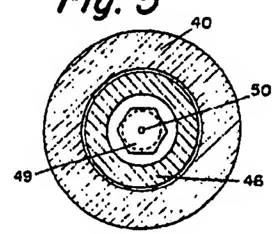


Fig. 5

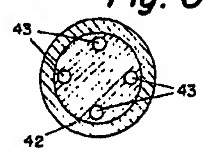


Fig. 6

Fig. 8

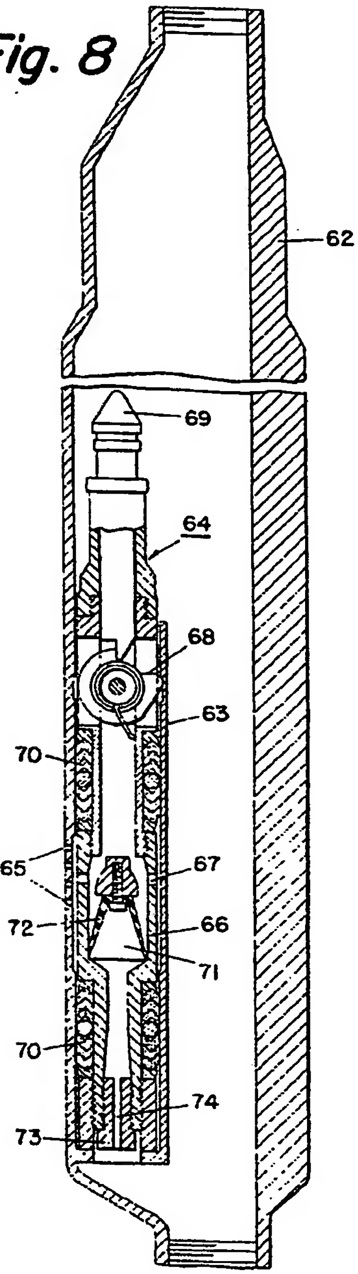
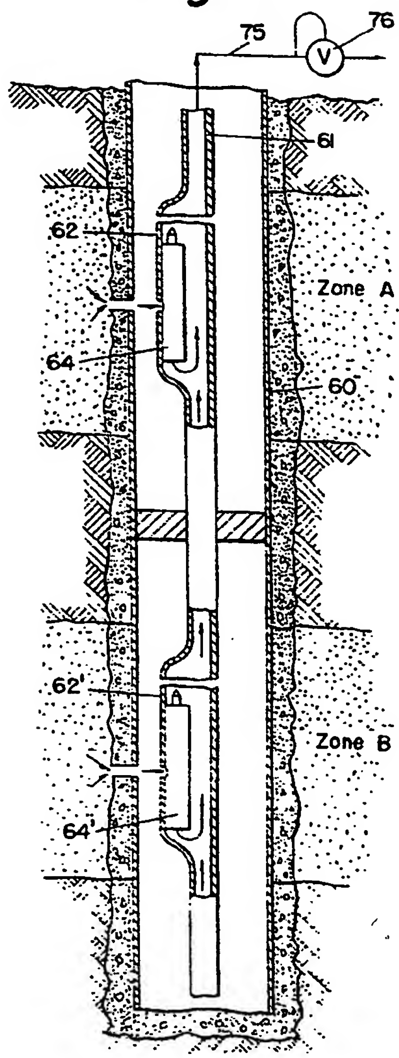

62
69
64
68
63
70
65
67
72
66
71
70
74
73

Fig. 7


75
76
V
61
62
Zone A
64
60
62'
Zone B
64'

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5 SHEETS

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SHEETS 4 & 5

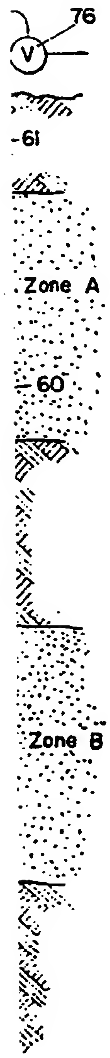


Fig. 9

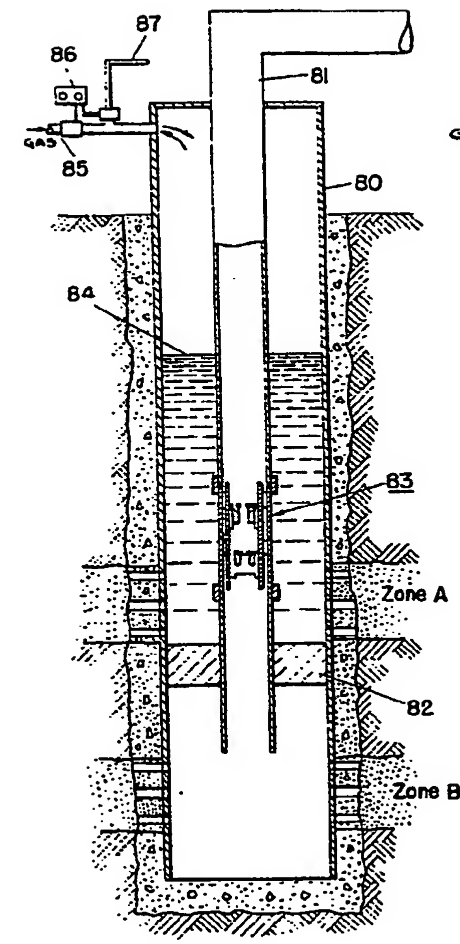
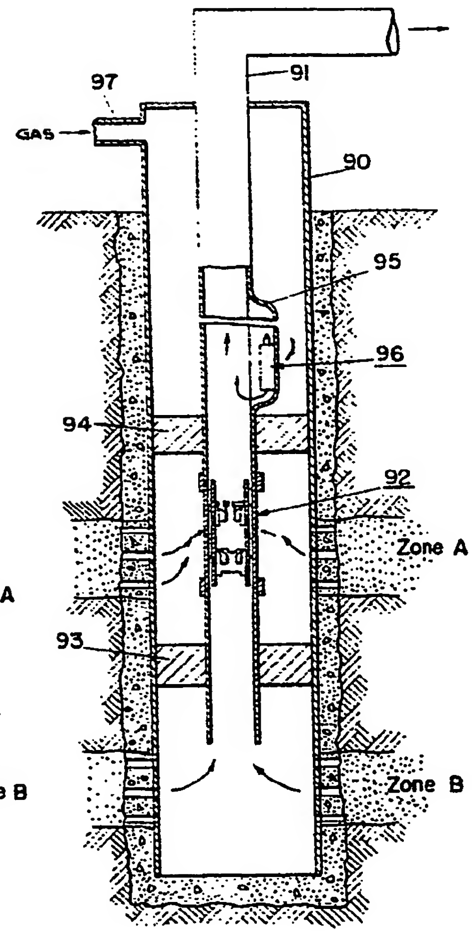


Fig. 10



851,096 COMPLETE SPECIFICATION
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SHEETS 4 & 5

Fig. 8

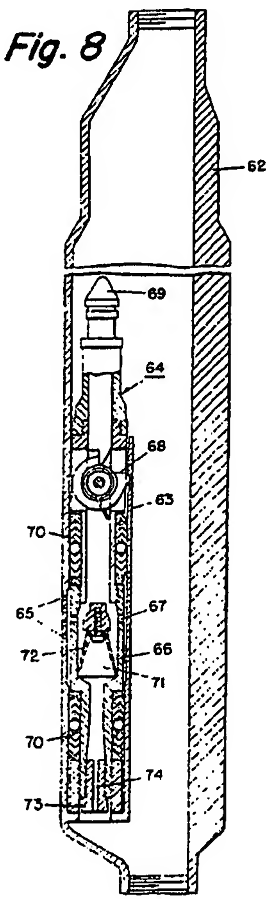

Fig. 7

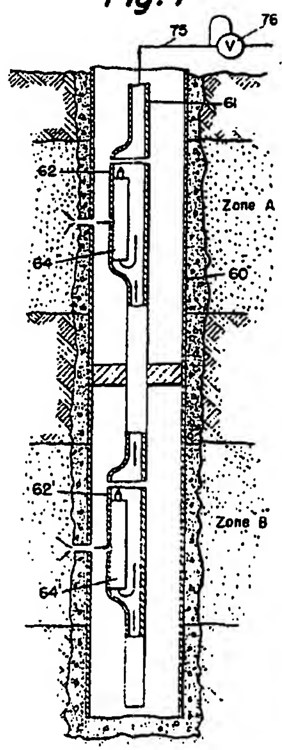

Fig. 9

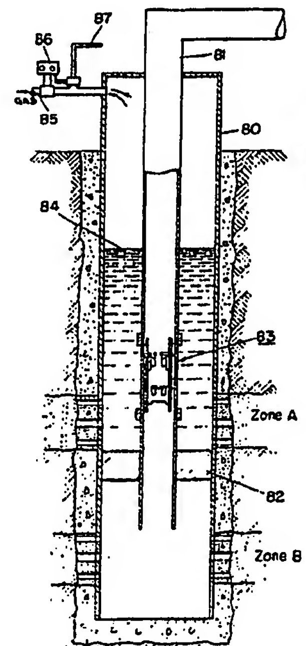

Fig. 10